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HISTORY OF THE PENNSYLVANIA AVENUE SUBWAY, PHILADELPHIA, AND SEWER CONSTRUCTION CONNECTED THEREWITH.

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PRESENTED MARCH 21ST, 1900.

WITH DISCUSSION.

It is the purpose of this paper to present the more interesting features of the history of the work of abolishing grade crossings on Pennsylvania Avenue, in the City of Philadelphia, by what is known as the Pennsylvania Avenue Subway, and also the construction of the sewers connected therewith.

GENERAL DESCRIPTION.

The Philadelphia and Reading Railroad enters the densely populated portion of the City of Philadelphia by means of two principal systems:

First.—That from Wayne Junction, Tioga, and Ninth St. to the Reading Terminal at Twelfth and Market Sts., formerly on the New York Division.

Second.—That from Falls of Schuylkill, Belmont and Pennsylvania Ave., also connecting with the Reading Terminal near Twelfth and Callowhill Sts., formerly on the Main Line Division.

Both of these systems are now part of the Philadelphia Division.

In 1893 both of these lines contained a very large number of grade crossings, which were becoming more dangerous as the city grew and the population on the lines of the tracks increased.

On account of the large number of tracks which formerly crossed Broad St. at grade between Callowhill St. and Pennsylvania Ave., and because Broad St. is one of the widest and finest streets in the city, being, at the point referred to, on one of the principal routes from the center of the city to Fairmount Park, special attention had been directed for some years to an arrangement between the City of Philadelphia and the Philadelphia and Reading Railroad Company by means of which this particular grade crossing could be avoided.

On December 26th, 1890, an ordinance was approved by the Mayor, giving the Philadelphia and Reading Terminal Railroad Company the right to construct the Terminal Station at Twelfth and Market Sts., and connect by means of an elevated structure with the tracks of the Philadelphia and Reading Railroad Company at:

First.—A point near Broad St. and Pennsylvania Ave., and,

Second.—A point near Ninth St. and Fairmount Ave.

In consideration of this privilege the Philadelphia and Reading Railroad Company was, by means of changes of the grades of the streets, to abolish the grade crossings at Broad St. and Lehigh Ave., at Ninth St. and Columbia Ave., and at Broad St. and Pennsylvania Ave., all without expense to the city. By this ordinance, Broad St. was to be carried over the railroad at both Pennsylvania and Lehigh Aves. The plans for this change at Broad St. and Pennsylvania Ave. provided for raising Broad St. about 21 ft., and was known as the "Hump" plan.

After the construction of the bridge, with its approaches at Lehigh Ave., in the northern section of the city, it was demonstrated clearly that a similar raising of the grade at Pennsylvania Ave., almost in the heart of the city, would not only seriously damage valuable property, but would practically ruin the finest avenue in the city, and would leave sixteen dangerous grade crossings to the westward unprovided for.

Before arrangements were made to begin work at Pennsylvania Ave., several plans were prepared by different interests, with a view of avoiding the hump on Broad St. One of these contemplated the abolishment of all grade crossings on the line of Pennsylvania Ave. and Noble St. from Thirteenth to Thirtieth Sts. by means of a tunnel extending from Hamilton St. to a point near Taney St., and the remainder of the line, including the freight yards of the railroad company, in an open subway with bridges on the line of Broad and other cross streets. This plan contemplated but a slight change in the grade of Broad St., and had the additional advantage of abolishing sixteen other dangerous grade crossings over Pennsylvania Ave., besides providing an entrance to Fairmount Park free from all danger and annoyance from passing trains.

The question of elevating the railroad tracks on the avenue was considered, but as this type of construction would result in all the intersecting streets being crossed by bridges, over which constant and heavy traffic would be passing, and particularly as, in addition to Broad St., these crossings would be over Twenty-second, Spring Garden and Green Sts., and Fairmount Ave., all principal entrances to Fairmount Park, the scheme was objected to seriously by citizens in the central and southern portions of the city. The bridge proposed at Broad St. was specially protested against as, on account of the crossing being in the center of the railroad terminal at this point, the width of the overhead bridge would have been 265 ft., thus practically making a tunnel of this length over the street, and cutting off the view on the central boulevard of the city.

After the preparation of a number of studies by the engineers of the city, of the Philadelphia and Reading Railroad, and by the late John A. Wilson, M. Am. Soc. C. E., Consulting Engineer for the Railroad Company, a plan and estimates were prepared for depressing the tracks and carrying them in subway and tunnel beneath all the streets from and including Broad St. to the west as far as Thirtieth St., permanently abolishing all the grade crossings, providing for the railroad business and for the maintenance of adequate track connections along the avenue from Thirteenth to Twenty-second Sts.

The advantages of a subway are that it does not disfigure the streets which cross it, the grades being so arranged that the superstructures of the bridges are beneath the level of the streets, and the

contour therefore remains unbroken. By means of the tunnel from Twenty-second St. to the west, the tracks are removed from sight, and what was formerly a half-blighted section of the city will be reclaimed, obtaining for the city a splendid driveway and an appropriate entrance to Fairmount Park freed from all objectionable features. It will also result in a partial financial return in increased taxes. From a railroad standpoint, it will do away with the constant expense of watchmen, the maintenance of safety gates, and will allow of the rapid running of trains on a clear permanent way, besides practically doing away with all claims arising from accidents to the public.

Legislation.

In the spring of 1894, a printed draft of an ordinance for the work generally described above, together with lithographs of bird's-eye views of Pennsylvania Ave. as it existed at that time and as it was proposed to change it, was placed in the hands of Common and Select Councils, the Legislative bodies of the city, together with an estimate of the total cost of the work, which was placed at $6 000 000. These lithographs are reproduced in Figs. 1 and 2 and show clearly the intent of the work to the average layman.

On March 15th, 1894, an ordinance was approved by the Mayor, then the Honorable Edwin S. Stuart, providing for the issuance of a loan of $6 000 000 to be used for the work. The ordinance provides that the city shall negotiate the loan, as specially provided, and the railroad company shall eventually pay back to the city half the cost of the work, providing that their share of the said cost in no event exceeds the sum of $3 000 000. The loan to be issued in twenty series of $300 000 each.

On March 17th, 1894, an ordinance was approved by the Mayor, for carrying out the work in substantial accordance with the general plans previously mentioned.

The work authorized by this ordinance involved the depression of the tracks and yards of the Philadelphia and Reading Railroad Company between Broad and Thirtieth Sts., including the alteration of the lines and grades of the tracks and yards between the north side of Noble St. and Callowhill St., and between Eleventh and Broad Sts.; the alteration of the lines and grades of the tracks of the Philadelphia

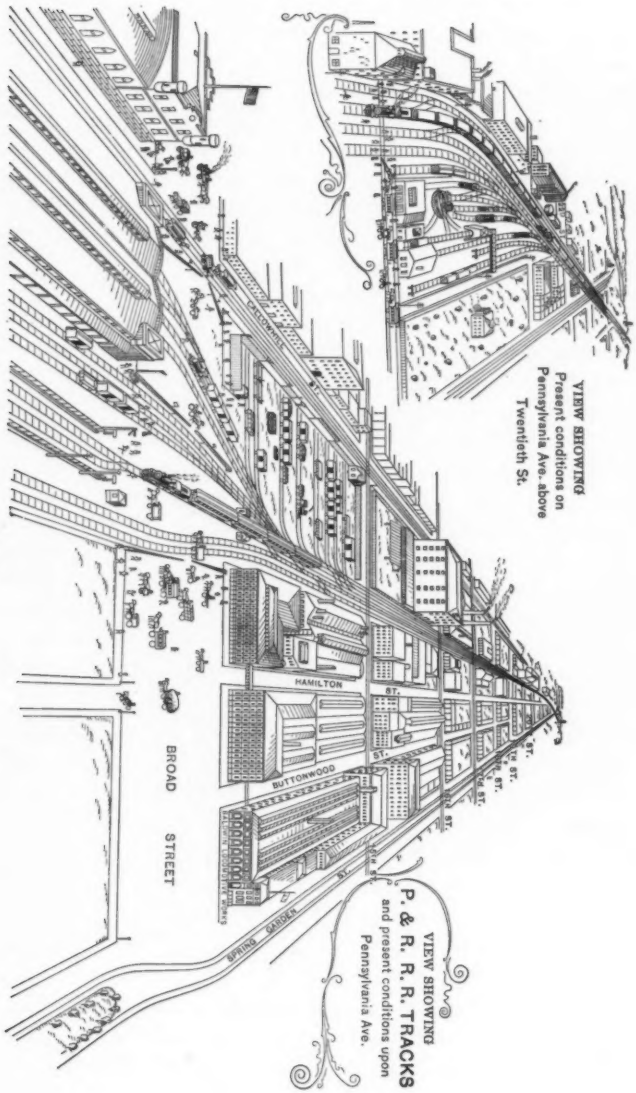

VIEW SHOWING
Present conditions on
Pennsylvania Ave. above
Twentieth St.
HAMILTON
ST.
BUTTONWOOD
ST.
BROAD
STREET
SPRING GARDEN
VIEW SHOWING
P. & R. R. R. TRACKS
and present conditions upon
Pennsylvania Ave.

FIG. 1.

and Reading Terminal Railroad Company, east of Broad St., and between Noble and Carlton Sts. Accompanying this depression and alteration of tracks and yards, is the alteration, construction and reconstruction of all the yard tracks, freight, engine, depot and signal buildings and other structures of the Philadelphia and Reading Railroad Company, so as to provide as much accommodation and as full and convenient a method for operation and conducting business as previously existing. Adequate track connections with the various industrial establishments along the line of the railroad were to be provided; provision was to be made for the construction of temporary tracks and bridges for maintaining travel on the railroad and upon all the intersecting streets. Bridges with adequate approaches, piers and abutments were to be built to carry Broad St., Fifteenth, Sixteenth, Seventeenth, Eighteenth, Nineteenth, Twentieth and Twenty-first Sts. over the tracks of the railroad. Bridges at Callowhill, Twelfth and Thirteenth Sts. were to be built to carry the tracks of the railroad over these streets. Provision was made for carrying the tracks in an open subway, with the necessary retaining walls and underpinning of all structures along the line, from a point near Broad St. to Hamilton St., by a tunnel from Hamilton St. to a point near Taney St., and thence by an open subway to a point near Thirtieth St. An entire reconstruction of the sewerage system between Twelfth and Thirtieth Sts. was made necessary, as well as the alteration and reconstruction of gas and water mains, electrical conduits and other municipal structures.

Twelfth, Thirteenth, Broad and a few of the other intersecting streets required some change of grade.

The lengths of the various classes of work to be constructed are as follows:

Elevated structure	959 ft.
Open subway	6 330 "
Tunnel	2 711 "
Total	10 000 ft.

On August 31st, 1894, a formal agreement* was entered into between the Receivers of the Philadelphia and Reading Railroad and the city,

*The form of agreement and ordinance in full have been filed in the Library of the Society for reference.

VIEW
SHOWING EAST ENTRANCE
TO TUNNEL AT 21st ST AND ROADWAY
AT PENNSYLVANIA AVE.
as it will appear
after the tracks have
been depressed
SKETCH
illustrating the plan for
the depression of
P. & R. R. R. TRACKS
ON
PENNSYLVANIA AVE.
WEST OF BROAD ST.
and
the abolishment of Grade
Crossings
on all intersecting streets
BROAD ST.
SPRING GARDEN ST.
BUTTONWOOD ST.
HAMILTON
21ST ST.
PENNSYLVANIA AVE.
FREIGHT HOUSE
Schuylkill

Fig. 2.

in compliance with the terms of the ordinance, which provided that before the ordinance should go into effect the Railroad Company should file its acceptance of the provisions contained and a covenant should be entered into, in form to be approved by the City Solicitor, to perform all the provisions of the ordinance as far as they relate to the Railroad Company.

On the same day they also filed a bond for $500 000, as required, as security for their payment to the City of half the total cost of the work.

On August 31st, 1894, the general plans for the construction of the work were approved, as required by the ordinance, and on August 30th bids were received for the work upon the entire sewerage system, the detailed plans for which had been prepared in anticipation.

The ordinance specifically provides that all the engineering work is to be done by the City under the supervision of the Director of the Department of Public Works, and that the plans and specifications, after being prepared, are to be submitted to the officers of the Railroad Company for their approval, and copies filed with the Railroad Company and the City.

Provision is also made for the necessary revisions of the lines and grades of the streets in order to carry out the work.

Fig. 3 is a general plan of the work and the surroundings.

Soundings.

A large number of soundings, by the water-jet process, were made along the line of the subway and on the route of the sewers, in order to give the contractors for the sewers an idea of the character of the material to be excavated, and to aid in making intelligent designs for the work of underpinning the buildings and for the main work of construction of the subway proper. Subsequent excavations, adjacent to these soundings, developed the fact that they had been made carefully, and were therefore of the greatest value in designing the work and making intelligent estimates. On account of the soft nature of the rock in many places, shown on the soundings as hard rock, it would have been well if a limited number of diamond drill borings had been made in selected localities along the line, in order to determine the nature of the rock more exactly.

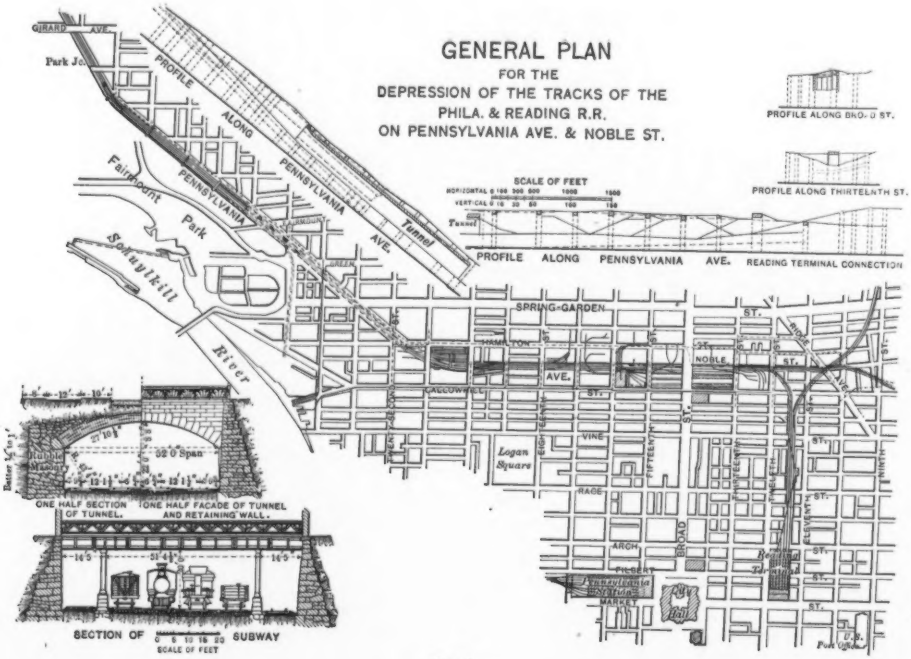

GENERAL PLAN
FOR THE
DEPRESSION OF THE TRACKS OF THE
PHILA. & READING R.R.
ON PENNSYLVANIA AVE. & NOBLE ST.
GIRARD AVE.
Park Jc.
PROFILE ALONG PENNSYLVANIA AVE.
Fairmount Park
Schuylkill River
Tunnel
SCALE OF FEET
PROFILE ALONG BRO-D ST.
PROFILE ALONG THIRTEENTH ST.
PROFILE ALONG PENNSYLVANIA AVE. READING TERMINAL CONNECTION
SPRING-GARDEN ST.
NOBLE ST.
CALLOWHILL ST.
VINE ST.
RACE ST.
ARCH ST.
MARKET ST.
BROAD ST.
Logan Square
City Hall
Reading Terminal
ONE HALF SECTION OF TUNNEL.
ONE HALF FACADE OF TUNNEL AND RETAINING WALL.
22'0 Span
SECTION OF SUBWAY
SCALE OF FEET

FIG. 3.

Sewers.

In order to drain the subway, and to provide for the old sewers cut by the excavations, three new and independent systems of main sewers were necessary to accomplish this purpose in the most satisfactory and economical manner, there being no existing systems at a sufficiently low level.

The three systems into which the sewers for carrying on this work were divided are as follows:

First. The Twenty-fourth Street and Pennsylvania Avenue System.—This system provides for the drainage west of Twenty-fourth St. on the north side of Pennsylvania Ave., intercepting all the cross sewers between Twenty-fourth and Thirtieth Sts., carrying the same beneath the tunnel at Twenty-fourth St., down Twenty-fourth St. to Powelton Ave., and on the line of Powelton Ave. to the Schuylkill River. This system was divided, for construction purposes, into two contracts.

Second. Callowhill Street System.—This system provides for the drainage of the subway and tunnel from Thirteenth to Twenty-third Sts. by means of a main sewer on Callowhill St. (which runs parallel to Pennsylvania Ave., east of Twentieth St.) with appurtenant sewers on the cross streets leading under the subway and receiving through wellholes the sewage from the old high-level sewers to the north. From Twenty-third St., the main sewer follows Powelton Ave. to Twenty-fourth St., passes along Twenty-fourth St. to Wood St. and thence to the Schuylkill River. This system is divided, for construction purposes, into three contracts.

Third. Twelfth Street System.—This system is designed to intercept the old Thirteenth St. main sewer, carry it down Buttonwood St. to Twelfth St., thence along Twelfth St. to Carlton St., where it discharges into an old main sewer on the Delaware River water-shed. This system is in one contract.

Detail plans were prepared for these sewers and special specifications written upon the same lines as those in use by the Sewer Division of the Bureau of Surveys (the City Bureau having charge of all sewer work). The sewers were contracted for at a price per lineal foot for each size of completed sewer, including excavation, refilling and all appurtenances shown on the drawings, such as manholes, wellholes, spurs, etc.

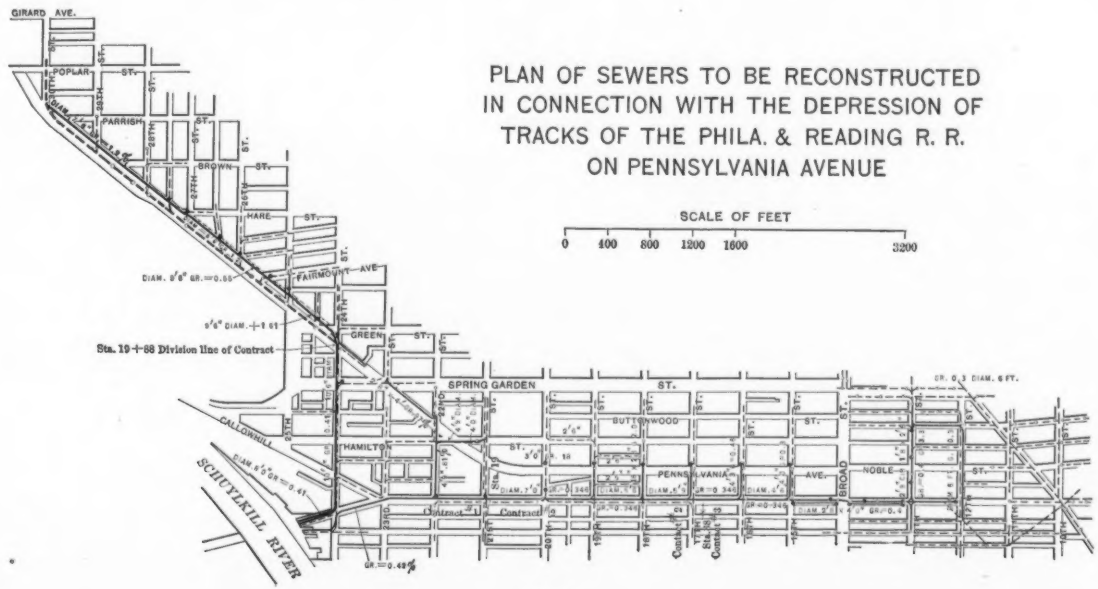

PLAN OF SEWERS TO BE RECONSTRUCTED
IN CONNECTION WITH THE DEPRESSION OF
TRACKS OF THE PHILA. & READING R. R.
ON PENNSYLVANIA AVENUE
SCALE OF FEET
0 400 800 1200 1600 3200
GIRARD AVE.
POPLAR ST.
PARRISH ST.
BROWN ST.
HARE ST.
FAIRMOUNT AVE
GREEN ST.
SPRING GARDEN ST.
CALLOWHILL ST.
HAMILTON ST.
BUTTONWOOD ST.
PENNSYLVANIA AVE.
BROAD ST.
NOBLE ST.
SCHUYLKILL RIVER
Sta. 19+88 Division line of Contract
Contract 1
Contract 2
Contract 3
DIAM. 5'6" GR.=0.55
DIAM. 7'0" GR.=0.41
GR.=0.48%
GR. 0.3 DIAM. 6 FT.

FIG. 4.

These specifications,* while covering the whole work of construction in detail, specify some features which are rather different from usual practice, and are, therefore, worthy of special attention.

It was directed that all sewers, wherever practicable, were to be constructed in tunnel, the work being carried on day and night.

All appliances for removing excavated material were to be specially adapted for the prevention of interference with travel, and were to be subject to the approval of the Chief Engineer.

When constructed in tunnel, the space between the outside of the sewer and the roof and sides of the tunnel was to be filled compactly with rubble masonry or concrete, as directed.

On account of the light grades, the inverts on curves were to be plastered with Portland cement mortar, ½-in. thick, to reduce the friction.

In the general clauses relating to the responsibility of the contractors and to maintenance, provision is made to settle disputes between the contractors on the several sections as to the disposition of drainage by making the Director of the Department of Public Works the arbiter. The maintenance of all new work is to be cared for by the contractor or his sureties for five years from its completion. The manner, the times of carrying on the work and the force used in construction are to be subject to the approval of the Chief Engineer.

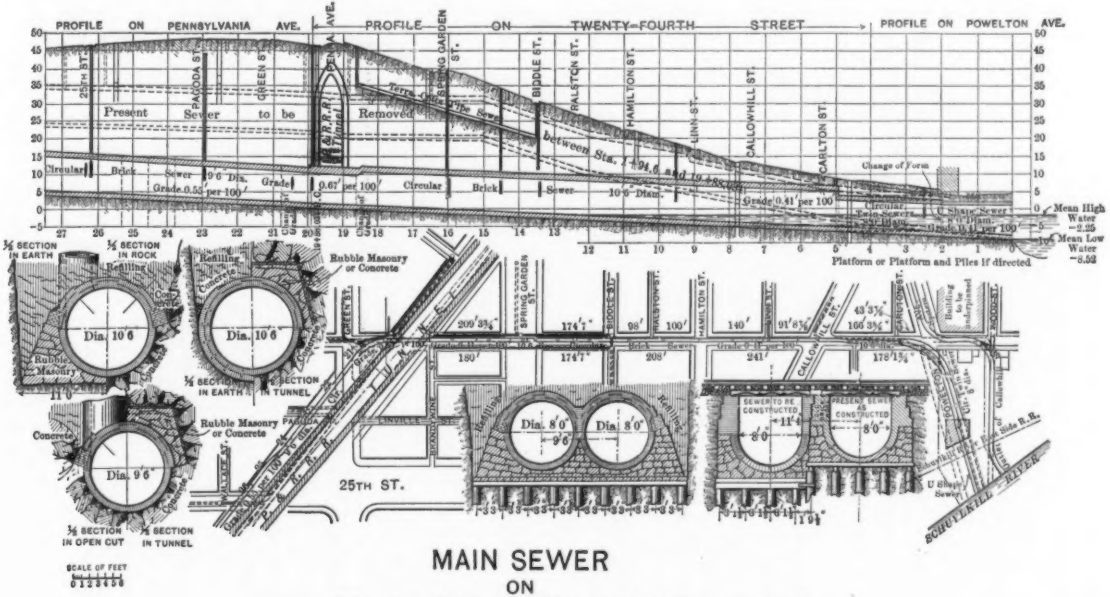
The general drainage plan of this work is shown in Fig. 4.

The time for the completion of the work was fixed by the department at four months from the date of the order to proceed.

Bids were received on August 30th, 1894, and on September 4th and 5th contracts were executed, as follows:

Contractors.	Limit of Contract.
Twenty-fourth St. and Pennsylvania Ave. System:	
Contract No. 1.—Ryan & Kelly	$102 000
" No. 2.—J. A. Mundy & Bro.	138 000
Callowhill St. System:	
Contract No. 1.—C. P. Grim & Co.	94 000
" No. 2.—Geo. W. Ruch	75 000
" No. 3.—John McCann	47 000
Twelfth St. System:	
John McCann	25 000

* The full specification has been placed on file in the Library of the Society.



MAIN SEWER
ON
24th ST. AND PENNSLVANIA AVE.

Between the outlet at Powelton Ave., and 30th St.

SCALE OF FEET 60 0 100

FIG. 5.

The order to proceed with the work was given to all contractors alike on September 10th, 1894, and it was directed that the work be proceeded with, day and night.

Detailed descriptions of the work on each contract follow.

Twenty-fourth Street and Pennsylvania Avenue System. Contract No. 1.—Located on the line of Powelton Ave., Twenty-fourth St. and Pennsylvania Ave., from the Schuylkill River to Station 19 + 88. Ryan and Kelly, Contractors.

This contract extended from the Schuylkill River at the foot of Powelton Ave. to the north of and alongside of an old 8-ft. U-shaped sewer; passed, with very close clearance, under the tracks of the Schuylkill River East Side Railroad (Baltimore and Ohio System) and, at a distance of about 205 ft. from the outlet, changed to an 8-ft. twin sewer. At the wharf, the elevation of the inside bottom of the invert is — 7.5, Philadelphia City datum. This datum is 2.25 ft. above mean high water and 8.52 ft. above mean low water in the Delaware River at Philadelphia. It is thus seen that the inside bottom of the sewer is only 1.02 ft. above mean low water. From this point, for a distance of about 150 ft., the sewer was constructed upon piles with a yellow pine platform and masonry cradle. The details of this section of the sewer are shown in Fig. 4. At about Station 1 + 50 the sewer runs beneath an old warehouse. Here, the piles were omitted and a timber platform 22 ins. thick was substituted. As will be seen by reference to Fig. 5, the pile work was below low tide, and the excavation for a distance of over 100 ft. from the outlet was through an old wharf, making the use of a coffer dam impracticable. A diver was employed to cut off the tops of the piles after they had been driven, and the platform and cradle were placed in position at low tide, bulkheads being used wherever practicable to facilitate the work.

The U-shaped sewer was covered with steel I-beams and buckle-plates filled in on top with concrete. This construction was necessitated on account of the low level of the railroad tracks crossing at this point. It will be noticed by reference to the plans that the new main sewer on Twenty-fourth St. is 10 ft. 6 ins. in diameter. This could not be carried under the railroad tracks and preserve the required elevation of the inside bottom; hence, a separating chamber, placed at the intersection of Twenty-fourth St. and Powelton Ave., and leading to a pair of circular sewers 8 ft. in diameter, was designed. Where these

twin sewers passed under the tracks the section was again changed, as noted above. The U-shaped portion of the old sewer on this line was retained from the old warehouse to the outlet, and the new sewer was built to the north of it.

From the point where the twin sewers commence, to the end of the separating chamber, the foundation was upon two layers of 3-in. yellow pine plank laid at an angle of 60° to each other. From the separating chamber to the north side of Callowhill St. a simple masonry cradle was used, and at about this point the excavation was largely through rock. Just south of Hamilton St. tunneling was started, and continued to the end of the contract at Station 19 + 88. It was entirely through rock, with the exception of a gravel pocket beneath Pennsylvania Ave. A tunnel was also driven beneath Callowhill St. through soft material so as not to interfere with traffic on the street.

The old sewer on Twenty-fourth St. was 10 ft. in diameter, and was very old. There was a heavy and constant flow of sewage through it, and, owing to the heavy grade, the invert in many places was practically worn out and washed away. In several places, and for considerable distances, there was no brick-work whatever remaining. The new sewer was constructed on essentially the same alignment as the old one, but with a much flatter grade. Up to a point near Hamilton St., it was necessary to carry the water during construction by means of a flume of wood, rectangular in section and 6 ft. square, constructed under the west sidewalk of Twenty-fourth St., and to remove the old sewer entirely, in order to build the new one. This flume extended from Hamilton St. to about Station 1 + 90 where it discharged into the old U-shaped sewer. From Hamilton St. north, by careful working, a tunnel was driven, and the new sewer was constructed beneath the old one, which was in active service. Several breaks occurred in the bottom of the old sewer, allowing the sewage to fall into the workings beneath, but in no case causing injury or loss of life. Entrance to the tunnel was obtained through four side-shafts with drifts into the main tunnel. These shafts were generally located in the small cross streets off the line of Twenty-fourth St.

Of the total length of main sewer constructed, 1 988.03 ft., the length in tunnel was 1 001.03 ft. Ingersoll-Sergeant drills with 3½-in. cylinders were used, fed with compressed air through 3-in. and 4-in. service pipe from an Ingersoll-Sergeant Class "A" compressor with a

capacity of twelve drills. The compressors were supplied with steam from two 80 H.-P. horizontal boilers. Ten hoisting engines and twelve pumps constituted part of the contractors' plant.

The blasting for the flume, referred to, seriously damaged a number of houses on the west side of Twenty-fourth St., which were in a very bad condition previous to beginning work. This damage was made good by the contractor, under the terms of his contract.

Progress in making the excavation for the new sewer tunnel was

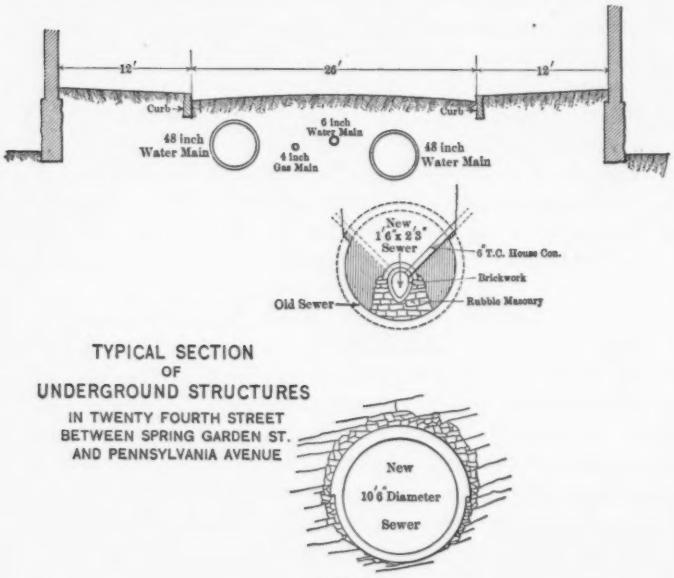


FIG. 6.

necessarily slow, on account of the dangerous proximity of buildings, the old sewer and one 6-in. and two 48-in. water mains in the street above the tunnel. Fig. 6 is a section through the street, between Spring Garden St. and Pennsylvania Ave., in which these structures were found. Work was begun September 10th, 1894, and was pushed vigorously day and night. The last sewer connection was made May 6th, 1895. The photographs on Plate I were taken from the open cut and tunnel work on this contract.

FIG. 1.—OPEN CUT ON 24TH STREET, NORTH OF CALLOWHILL STREET.

FIG. 2.—TUNNEL ON 24TH STREET, UNDER PENNSYLVANIA AVENUE.

TABLE No. 1.—Lengths, Sizes and Prices Paid.

Sizes and Shapes.	Contract price, per lineal foot.	Total length, in feet.	Length in tunnel, in feet.
8 ft. diameter, U-shaped	$47.78	205.30	
8 ft. diameter, twin	58.51	293.32	
10 ft. 6 ins. diameter with 12-in. pipe.	43.00	1 337.08	877.70
9 ft. 6 ins. diameter	45.00	123.33	123.33
Separating chamber	86.02	29.00	
		1 988.03	1 001.03

Total payment to contractors: $92 586.42.

Twenty-fourth Street and Pennsylvania Avenue System. Contract No. 2.—Located on the line of Pennsylvania Ave. from Station 19 + 88 to Thirtieth St. James A. Mundy and Brother, Contractors.

This is a continuation of Contract No. 1, and completes the system by making connection with the old sewer on Thirtieth St. The sewer, where it crosses under Twenty-fourth St., is 9 ft. 6 ins. in diameter and gradually decreases in size to 7 ft. 6 ins., which is the size of the old sewer on Thirtieth St. Of the total length of main sewer on this contract, 3 470.66 ft., the length in tunnel was 2 878.02 ft. Access to the tunnel was obtained through sixteen shafts, generally located where manholes or wellholes occurred. Very little soft material was encountered in making the excavation, although frequent timbering in isolated places was required, on account of the dip and seamy character of the rock, which was a mica schist of very irregular character and hardness, in some places being badly decomposed, even where 40 ft. beneath the natural surface. At the lower end of the contract, on the curve running west from Twenty-fourth St., the rock was unusually slippery when exposed to the air, and required careful watching. Just west of Twenty-eighth St., the tunnel excavation passed through a fill, formerly the bed of an old creek, and considerable difficulty was experienced in making the timbering stable.

From Brown St. to Thirtieth St. the sewer was built in open cut.

From Twenty-fourth St. to Fairmount Ave. the tunnel passed beneath a large number of dwelling houses and an ice-manufacturing plant, the latter in active operation and the former occupied. These structures were finally removed, upon the widening of Pennsylvania Ave., and the sewer is now in the bed of the street. With the exception of breaking a 48-in. water main, no serious injury was done

by the blasting. From Fairmount Ave. westward, the line of the sewer is generally distant from any buildings.

Drills of the Rand type, with 3½-in. cylinders, were used, and were fed with compressed air through 4, 6 and 8-in. service pipes from two Rand compressors with a joint capacity of thirteen drills. The compressors were supplied with steam from two 75 H.-P. horizontal boilers. Seven hoisting engines and six pumps constituted part of the contractors' plant.

Work was begun September 10th, 1894, and was pushed day and night. The last sewer connection was made April 16th, 1895. Fig. 1, Plate II, shows the work in tunnel on this contract.

TABLE No. 2.—Lengths, Sizes and Prices Paid.

Sizes.	Contract price, per lineal foot.	Total length, in feet.	Length in tunnel, in feet.
9 ft. 6 ins. diameter.....	$49.33	1 382.70	1 382.70
8 ft. 6 ins. diameter.....	35.99	870.26	870.26
7 ft. 6 ins. diameter.....	20.38	1 217.70	625.06
		3 470.66	2 878.02

Total payment to contractors: $126 496.15.

Callowhill Street System. Contract No. 1.—Located on the line of Wood St., Twenty-fourth St., Powelton Ave. and Callowhill St. from the Schuylkill River to Station 19 at Twenty-first St., with appurtenant sewers on Twenty-second St., Hamilton St. and Pennsylvania Ave., C. P. Grim and Company, Contractors.

This contract is the outlet and most difficult section of the Callowhill St. System. From a point near Twenty-fourth St. to the Schuylkill River, the sewer followed the line and approximately the grade of the old Wood St. sewer, which is about 4 ft. in diameter. Near the crossing of the Baltimore and Ohio Railroad, the new sewer cut through part of the old wharf referred to on the Twenty-fourth St. System. At the outlet, the elevation of the inside bottom of the invert is — 8.17, or only 0.35 ft. above mean low water.

From the outlet to Station 1 + 40 the sewer is 8 ft. 6 ins. in diameter with an 18-in. arch, and is constructed upon a platform placed upon piles and with a masonry cradle. The piles and platform extended to about Station 1 + 40, where a timber platform was

FIG. 1.—TUNNEL ON PENNSYLVANIA AVENUE, WEST OF 26TH STREET.

FIG. 2.—SEWER IN TUNNEL ON CALLOWHILL STREET.

commenced. During the construction of the new sewer on the line of Wood St. it was necessary to flume the sewage from the old sewer, and, at the outlet, to work only at the lowest stages of the tide. It was impossible to place bulkheads at any point to prevent ingress of the tide, on account of the structure of the old wharf.

At the southeast corner of Twenty-fourth St. and Powelton Ave. the sewer approaches very closely to the three-story brick building of Bement, Miles and Company, used as a store house for patterns of machine tools, and, on account of the admittedly bad character of the foundation under the walls of this building, it was not considered advisable to proceed with the excavation without first underpinning the building. A supplementary contract was therefore made with the contractors for this underpinning.

The special specifications prepared for this work required the excavation to be made by sinking shafts, not adjacent to each other, and shoring the sides carefully where necessary. All loose or imperfect stones in the bottom of the old foundation were required to be removed, until such portions of the same were reached as were compact and the stones of large size. At the center of each section (generally 4 ft. long), and under the prepared bottom of the foundation wall, a timber of long-leaf yellow pine 10 by 10 ins. in section was to be placed and firmly wedged up with iron or steel wedges. The space around the timber and under the wall was filled with masonry of stone with specially flat beds (the stone from Conshohocken, Montgomery County, Pa., was specified), laid in Portland cement mortar, mixed in the proportion of 1 part cement to 1 part sand. This masonry was required to be wedged up firmly so that no space was left for settlement.

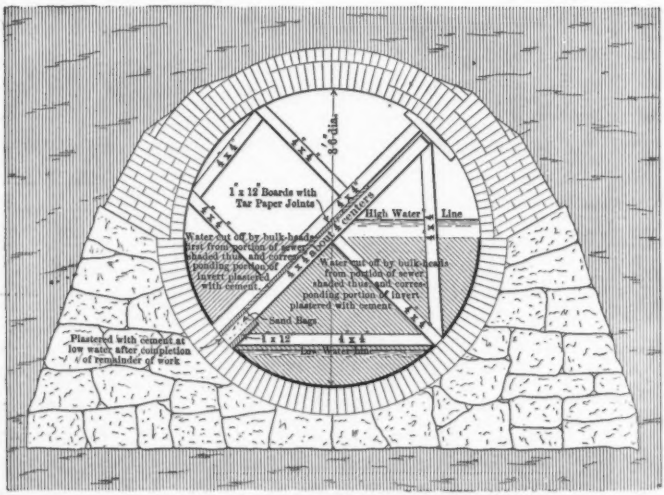
The excavation was carried down through river mud and sand for a distance of 20 ft., and was stopped on a bed of compact gravel below the bottom of the excavation required for the sewer. A bed of concrete about 4 ft. wide and 3 ft. deep was laid as a footing course. The building thus underpinned contained a number of cracks previous to the operation, but no new cracks were started, nor were any of the old ones increased in size. The price paid for the underpinning, including the excavation and all appurtenances, was $18 per cubic yard.

On the line of Powelton Ave., the excavation was in open cut through a bed of gravel as far as Callowhill St., where a tunnel was

driven beneath this street and Twenty-third St. in order to keep the streets open to travel. While driving this tunnel, and on the line of Twenty-third St., an old sewer, about 3 ft. in diameter, was encountered, of which there was no record on the city drainage plans. This sewer carried very large volumes of water at certain hours of the day when the dye mills in the vicinity emptied their tanks. This caused the contractors much annoyance and expense in maintaining the flow of the sewage. From Twenty-third St. to a point west of Twenty-second St., the excavation was in open cut, the contractors using, on this section, a Carson sewer-trench machine. A second unrecorded sewer, running diagonally beneath the adjacent houses, was cut about the middle of this block. The volume of water carried by it however, was very small and was easily cared for. From a point just west of Twenty-second St. to Station 19, the end of the contract on Callowhill St., and to the end of the appurtenant sewers at Twenty-first and Hamilton Sts. and Twenty-second St. and Pennsylvania Ave., the excavation was made in tunnel, with the exception of a short length at Twenty-first and Hamilton Sts. The tunnel was entered by means of eight shafts so located as to be off the main streets. The total length of the sewers on this contract was 3 094.61 ft., of which the length constructed in tunnel was 1 751.87 ft. Under Callowhill St. the tunnel was in soft ground, the remainder was through rock of varying degrees of hardness. Drills of the Ingersoll-Sergeant, Rand and Kerner types, with 3-in. cylinders, were used. They were fed with compressed air through a 4-in. service pipe from a Blake duplex compressor with a capacity of eight drills. The compressor was supplied with steam from two vertical boilers with a combined horse-power of 70. The contractors had in use four hoisting engines and ten pumps.

The contractors on this section did not prosecute their work as rapidly as they should, and, as they finished their brick-work, they failed to plaster the inverts on curves as required by the specifications. As a consequence, they were compelled to care for the full flow of the sewers on the contracts above them, and plaster the inverts and maintain the flow of the sewer at the same time. In order to accomplish this, a longitudinal flume, the full length of the curve, was constructed, as shown in section in Fig. 7. Bulkheads of sand bags were then built at each end of the flume in the spaces shown by the smallest shaded

area, and the flow of sewage or the returning tide made to pass beneath. The smaller segment of the invert, being free from water, was then plastered. As soon as the plaster had set, the bulkheads were removed and placed in the spaces shown by the largest shaded area, and the flow made to pass on top of the flume. The larger segment was then plastered. After the flume was removed from the sewer, the spaces on the invert occupied by the framing were plastered at low water, they being purposely arranged so as to be above water at low tide and at ordinary stages of the flow in the sewer. During its


1" x 12" Boards with Tar Paper Joints
High Water Line
Water cut off by bulk-heads from portion of sewer shaded thus and corresponding portion of Invert plastered with cement
Sand Bags
Plastered with cement at low water after completion of remainder of work
Pipe Water Line

SECTION OF CALLOWHILL ST. SEWER
SHOWING FLUME USED FOR PLASTERING INVERT ON CURVES
SCALE OF FEET
0 1 2 3 4 5 6

FIG. 7.

use the flume was endangered by two severe rain storms. Sufficient warning was given, however, to enable men to enter the sewer and remove the bulkheads by throwing the sand bags on the bottom, thus reducing the obstruction to a minimum. No damage resulted in either case.

The plastering upon brick over which sewage had been running was a piece of work which required great care and skill, in order to make a good finish. In some cases, where the ground-water was

large in amount, weep holes were made through the brick. At such places, the bricks were thoroughly soaked with water, and there was considerable trouble in making the plaster adhere. In some cases, the grease from the sewage interfered with the proper adhesion, and had to be burnt off with plumber's blow-pipes. Experience with the conditions soon resulted in a very satisfactory piece of work. A quick-setting neat cement, worked as dry as possible, being used where the amount of water in the brick was greatest.

Work was begun September 10th, 1894, was pushed vigorously for a few months, and then carried on in a dilatory manner. The last sewer connection was made in November, 1895, and the plastering of the inverts was finished February 26th, 1896.

TABLE No. 3.—Lengths, Sizes and Prices Paid.

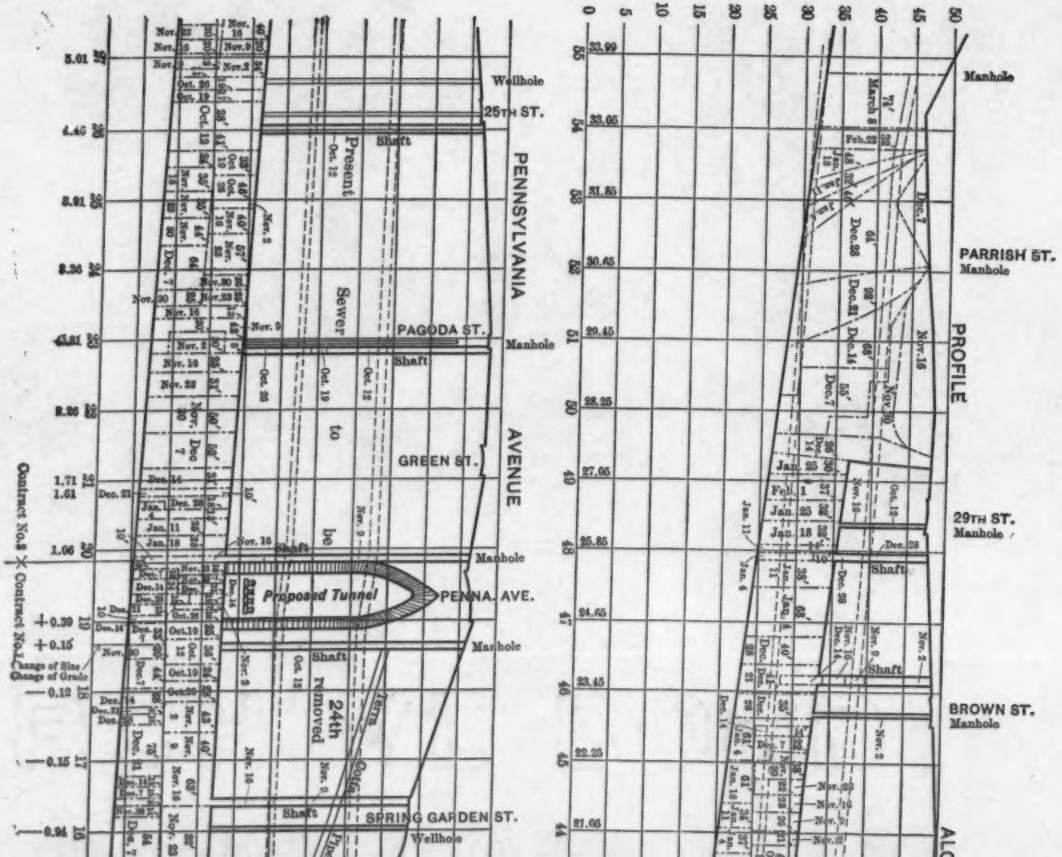
Sizes and shapes.	Contract price, per lineal foot.	Total length, in feet.	Length in tunnel, in feet.
8 ft. 6 ins. diameter, 18-in. arch	$72.50	140.00	.....
" " " 13½-in. arch	26.75	1 244.24	196.00
7 ft. diameter	27.15	516.73	516.73
4 ft. 9 ins. diameter	20.00	692.64	692.64
4 ft. diameter	17.25	250.00	95.50
3 ft. diameter	20.50	251.00	251.00
4 ft. by 2 ft. 8 ins., egg-shaped	8.00	not built.	.....
		3 094.61	1 751.87

Total payment to contractors: $80 342.75.

The 4 ft. by 2 ft. 8 in. egg-shaped sewer was not constructed, on account of its close proximity to the north wall of the tunnel, which had to be excavated in rock immediately adjacent. It was omitted, therefore, in this contract, and constructed after the excavation of the tunnel wall was made.

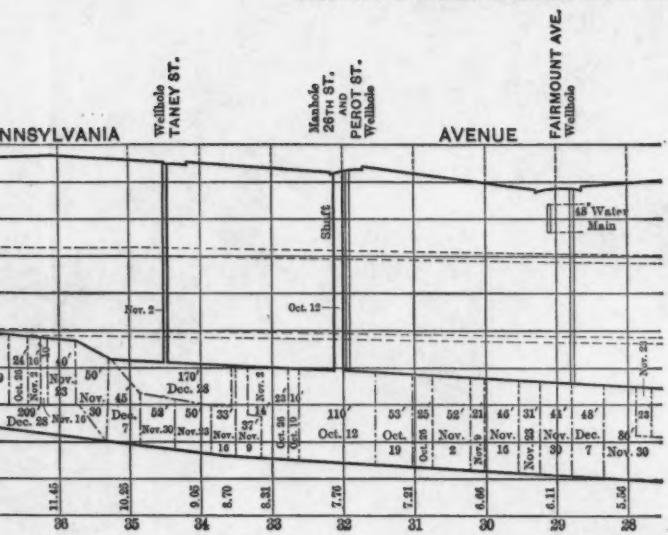
Callowhill Street System. Contract No. 2.—Located on the line of Callowhill St., from Station 19 at Twenty-first St., to Station 38 at Seventeenth St., with appurtenant sewers on Seventeenth, Eighteenth, Nineteenth and Twentieth Sts., George W. Ruch, Contractor. This was a continuation of Contract No. 1, and was the middle contract of the system.

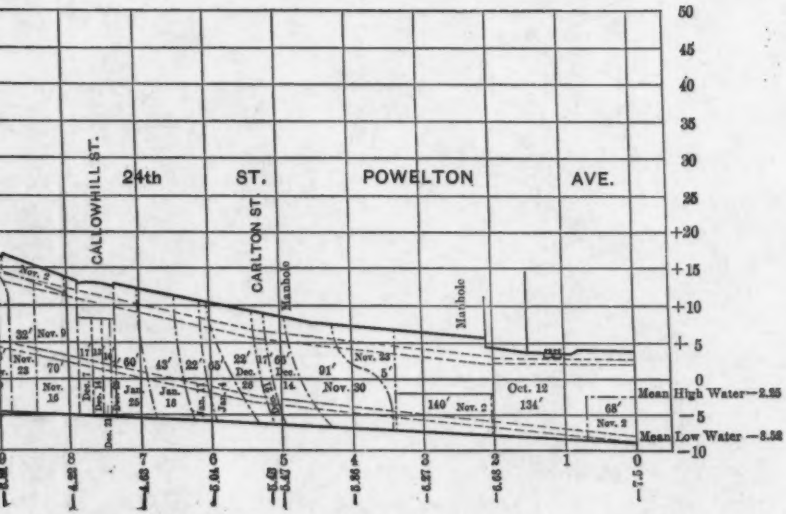
The whole of the 2 953.20 ft. of sewers constructed on this contract was built in tunnel, access to the headings being obtained through twelve shafts. At the western end of the line, the tunnel was driven through rock, and very little or no timbering was required. From


PENNSYLVANIA AVENUE
PROFILE
Present Sewer to be removed
Proposed Tunnel
Wellhole
25TH ST.
Shaft
PAGODA ST.
Manhole
GREEN ST.
PENNA. AVE.
24th
SPRING GARDEN ST.
Contract No.2
Contract No.3
Change of Size
Change of Grade
PARRISH ST.
29TH ST.
BROWN ST.
Manhole

ALONG
BROWN ST.
Manhole
Manhole
28TH ST.
PENNOCK ST.
Wellhole
Wellhole
HARE ST.
AND
27TH ST.
Manhole
PENNSYL
Shaft
Nov. 2
Oct. 12
Nov. 2
Nov. 2
Shaft
Nov. 2
Oct. 12
Oct. 12
Oct. 19
Oct. 26
Nov. 9
Oct. 12
Oct. 19
209'
Dec. 28
22.45
22.25
21.05
19.85
18.65
17.45
16.25
15.05
13.85
12.65
11.45
46
45
44
43
42
41
40
39
38
37
SPRING GARDEN ST.
Wellhole
Manhole
Manhole
BIDDLE ST.
Wellhole
RALSTON ST.
HAMILTON ST.
Manhole
LINN ST.
Terra Cotta Pipe Sewer
24th
removed
Shaft
Shaft
Shaft
Nov. 9
Oct. 12
Nov. 2
Nov. 16
Nov. 2
Oct. 12
Feb. 8
Nov. 2
Nov. 9
Change of Size
Change of Grade
— 0.12
— 0.15
— 0.94
— 1.35
— 1.78
— 2.17
— 2.53
— 3.09
— 3.40
— 3.58
18
17
16
15
14
13
12
11
10
9

PLATE III.
TRANS. AM. SOC. CIV. ENGS.
VOL. XLIV, No. 878.
WEBSTER AND WAGNER ON SUBWAY SEWER CONSTRUCTION.





Station 19 to a point near Nineteenth St., the excavation was through rock which decreased in hardness as the work progressed toward the east. Rock was encountered on Twentieth St., that under Pennsylvania Ave. being specially hard. On the other hand, the sewer on Seventeenth St. was driven through a micaceous sand, very slippery and dangerous to handle, and requiring close sheathing in the headings. The most serious accident on the work occurred on the Callowhill St. sewer, where it passed under the old high-level sewer on Nineteenth St. A cave-in occurred at this point, caused by insufficient timbering, the sewage from above filling the entire workings below. There was also trouble on Callowhill St., between Twentieth and Twenty-first Sts., caused by blasting. The blasts were so severe as to affect the adjustment of machine tools in the shops of Messrs. Bement, Miles and Company, immediately adjoining the line of the sewer, and spoiling some work which was on the machines. After several cautionary orders, the Department was compelled to direct the detailed operations of firing the charges, and, as a result, the contractor, at the termination of the work, sued the city for damages resulting from the issuance of such an order. The suit was entered by the contractor in the sum of $57 377.46, afterward revised, as agreed upon by counsel, to $52 785.16. The suit was tried in November, 1897, and was interesting on account of the testimony of an expert nature, presented by the contractor to show that the Chief Engineer had exceeded his authority by issuing orders directing the manner in which the blasting was to be done, when no special method was specified. The court ruled that the Chief Engineer had the right to issue such instructions if they were reasonable.

Testimony was presented by the city to show that the progress made in driving the tunnels was as great after issuing the order as it had been before. As this testimony could not be refuted, the case was settled, and a verdict of $8 705.13 was awarded the contractor. This verdict meant a practical victory for the city, as it represented retained moneys and interest on the same held by the city, pending the settlement of the case.

Drills of the Ingersoll-Sergeant type with 3½-in. cylinders were used. The compressed air was supplied through 3, 4 and 5-in. service pipes from a Norwalk single compressor, with a capacity of twelve drills. The compressor was supplied with steam from two

65 H.-P. vertical boilers. In addition to this machinery the contractor had in use five hoisting engines and five pumps.

Work was begun on September 20th, 1894, and the last sewer connection was made June 3d, 1895. Fig. 2, Plate II, shows the sewer construction in tunnel on Callowhill St., between Twentieth and Twenty-first Sts.

TABLE No. 4.—Lengths, Sizes and Prices Paid.

Sizes and shapes.	Contract price, per lineal foot.	Total length, in feet.	Length in tunnel, in feet.
7 ft. diameter	$29.65	967.00	967.00
6 ft. 6 ins. diameter	29.54	478.00	478.00
5 ft. 9 ins. diameter	26.29	455.00	455.00
3 ft. diameter	16.27	257.45	257.45
2 ft. 9 ins. diameter	16.27	265.25	265.25
3 ft. 3 ins. by 2 ft. 2 ins., egg-shaped	9.77	265.25	265.25
2 ft. 6 ins. by 1 ft. 8 ins., egg-shaped	10.35	265.25	265.25
		2 953.20	2 953.20

Total payment to contractors: $69 662.71.

Callowhill Street System. Contract No. 3.—Located on the line of Callowhill St., from Station 38 at Seventeenth St., to Thirteenth St., and on Thirteenth St. from Carlton St. to Buttonwood St., with appurtenant sewers on Fifteenth and Sixteenth Sts. John McCann, Contractor.

The total length of sewers on this contract was 2 467.97 ft., of which the length constructed in tunnel was 2 060.97 ft. Access was obtained through nine shafts. A considerable portion of the sewer on Sixteenth St., and the main sewer on Callowhill St. from east of Sixteenth St. to Station 38, was in rock; the remainder of the work was through soft material, much of it being a slippery micaceous sand, comparatively free from water. While the department would have allowed open cutting east of Broad St., on account of the soft character of the material, and because the depth of the sewer was not very great, the contractor elected to build the sewer in tunnel, and made very satisfactory progress, and without accident.

On account of the grade of Thirteenth St. being changed materially by the plans of the subway, it was deemed inadvisable by the department to dig up the street and construct the sewer at the time the rest of the sewer work was being done, on account of the double incon-

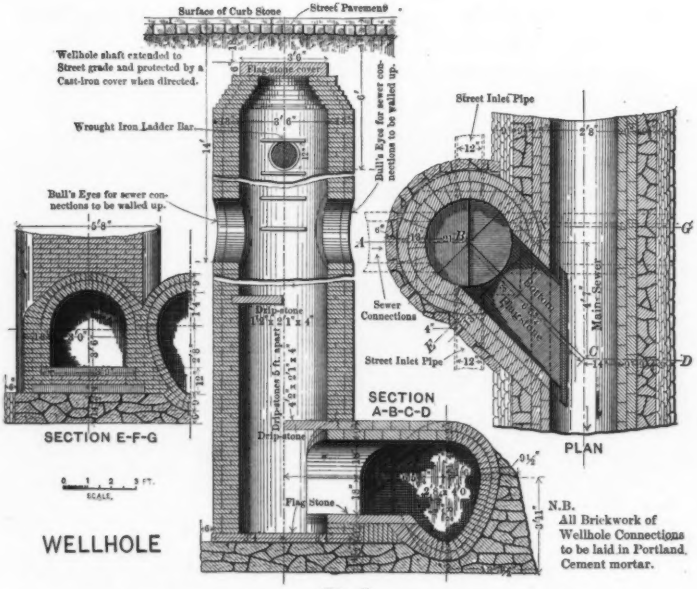
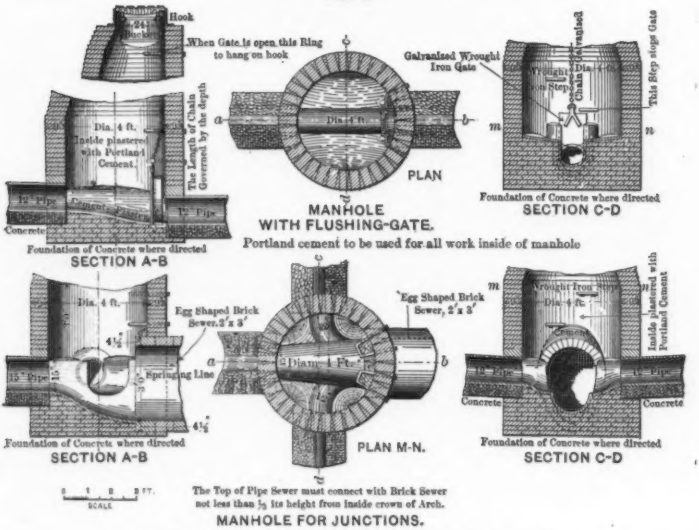

Surface of Curb Stone
Street Pavement
Wellhole shaft extended to Street grade and protected by a Cast-iron cover when directed.
Flag-stone cover
Wrought Iron Ladder Bar
Bull's Eyes for sewer connections to be walled up.
Bull's Eyes for sewer connections to be walled up.
Street Inlet Pipe
Sewer Connections
Main Sewer
Drip-stone
Drip-stones 5 ft. apart
Drip-stone
Street Inlet Pipe
SECTION A-B-C-D
PLAN
SECTION E-F-G
Flag Stone
WELLHOLE
N.B. All Brickwork of Wellhole Connections to be laid in Portland Cement mortar.

FIG. 8.


Hook
When Gate is open this Ring to hang on hook
Galvanized Wrought Iron Gate
This Step stops Gate
Dia. 4 ft. Inside plastered with Portland Cement.
The Length of Chain Governed by the depth
Foundation of Concrete where directed
SECTION A-B
PLAN
Foundation of Concrete where directed
SECTION C-D
MANHOLE WITH FLUSHING-GATE.
Portland cement to be used for all work inside of manhole
Egg Shaped Brick Sewer, 2' x 3'
Springing Line
Egg Shaped Brick Sewer, 2' x 3'
Inside plastered with Portland Cement
Concrete
Foundation of Concrete where directed
SECTION A-B
PLAN M-N.
Foundation of Concrete where directed
SECTION C-D
The Top of Pipe Sewer must connect with Brick Sewer not less than ⅓ its height from inside crown of Arch.
MANHOLE FOR JUNCTIONS.

GENERAL DETAILS FOR PIPE SEWERS.

FIG. 9.

venience to the public. No work was done on Thirteenth St., therefore, under this contract.

The contractor had no power drills or compressors on the work. All the drilling was done by hand.

Work was begun September 10th, 1894, and the last sewer connection was made May 18th, 1895. This connection was delayed, on account of the failure of the contractor on Contract No. 2 to complete the tunnel at the upper end of his section.

TABLE No. 5.—Lengths, Sizes and Prices Paid.

Sizes and Shapes.	Contract price, per lineal foot.	Total length, in feet.	Length in tunnel, in feet.
5 ft. 9 ins. diameter	$27.90	390.52	390.52
4 ft. 6 ins. diameter	12.84	438.21	438.21
4 ft. by 2 ft. 8 ins., egg-shaped	10.50	1 056.92	651.92
2 ft. 9 ins. diameter	11.00	not built.	not built.
2 ft. 6 ins. diameter	7.75	38.50	38.50
2 ft. 6 ins. by 1 ft. 8 ins., egg-shaped	5.75	not built,	not built.
12-in. T. C. pipe	2.40	" "	" "
4 ft. 3 ins. diameter	11.00	273.72	273.72
4 ft. diameter	11.70	253.75	253.75
Junction chamber	104.50	14.35	14.35
		2 467.97	2 060.97

Total payment to contractor: $35 976.81.

Twelfth Street System.—This contract extends on Twelfth St., Buttonwood St. and Thirteenth St., from Carlton St. to Whitehall St. John McCann, Contractor.

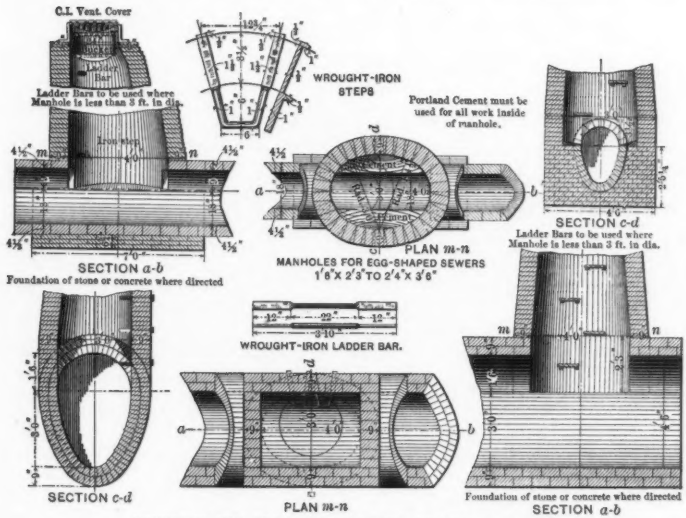
The sewer on this system was near the surface of the street and was constructed entirely in open cut. There were no points of special interest in connection with it.

Work was started September 10th, 1894, and the connection to the old sewer was made on December 29th, 1894.

TABLE No. 6.—Length, Size and Price Paid.

Size.	Contract price, per lineal foot.	Length.
6 ft. diameter.	$16.00	1 398.00

Total payment to contractor: $22 823.49.

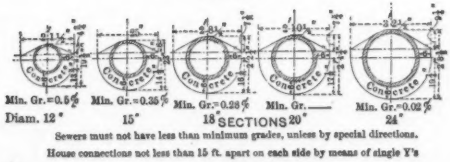

C.I. Vent. Cover
Ladder Bars to be used where Manhole is less than 3 ft. in dia.
WROUGHT-IRON STEPS
Portland Cement must be used for all work inside of manhole.
SECTION a-b
Foundation of stone or concrete where directed
PLAN m-n
MANHOLES FOR EGG-SHAPED SEWERS
1'6"X 2'3" TO 2'4"X 3'6"
SECTION c-d
Ladder Bars to be used where Manhole is less than 3 ft. in dia.
WROUGHT-IRON LADDER BAR.
SECTION c-d
PLAN m-n
Foundation of stone or concrete where directed
SECTION a-b

MANHOLES FOR EGG-SHAPED SEWERS OF MEDIUM SIZE.

GENERAL DETAILS FOR EGG-SHAPED SEWERS.

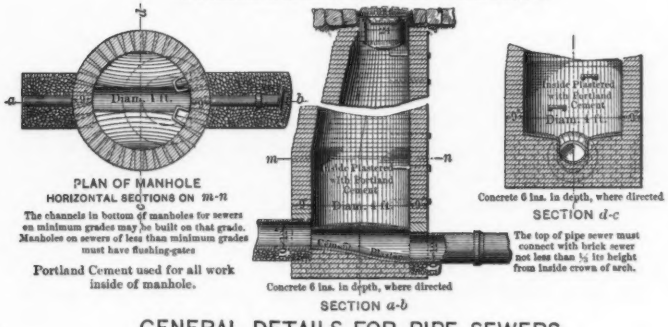
SCALE

FIG. 10.



Sewers must not have less than minimum grades, unless by special directions.

House connections not less than 15 ft. apart on each side by means of single Y's


Diam. 4 ft.
PLAN OF MANHOLE
HORIZONTAL SECTIONS ON m-n
The channels in bottom of manholes for sewers on minimum grades may be built on that grade. Manholes on sewers of less than minimum grades must have flushing-gates
Portland Cement used for all work inside of manhole.
Brick Plastered with Portland Cement
Diam. 4 ft.
Concrete 6 ins. in depth, where directed
SECTION a-b
Concrete 6 ins. in depth, where directed
SECTION d-c
The top of pipe sewer must connect with brick sewer not less than ⅓ its height from inside crown of arch.

GENERAL DETAILS FOR PIPE SEWERS.

SCALE

FIG. 11.

TABLE No. 7.—PRICES FIXED IN ALL SEWER CONTRACTS.

Additional rubble masonry in place, per cubic yard, including all appurtenances	$4.50
Additional brick masonry, in place, per cubic yard	9.50
Additional manhole with cover, without bucket	25.00
Additional wellhole, per vertical foot	5.00
Each inlet with cover or grating, as follows:	
No. 1	96 00
No. 2	87.00
No. 3	81.00
No. 4	45.00
No. 5	40.00
Additional terra-cotta pipe not in concrete, per lineal foot	1.10
" " " " " " "	1.35
" " " " " " "	0.50

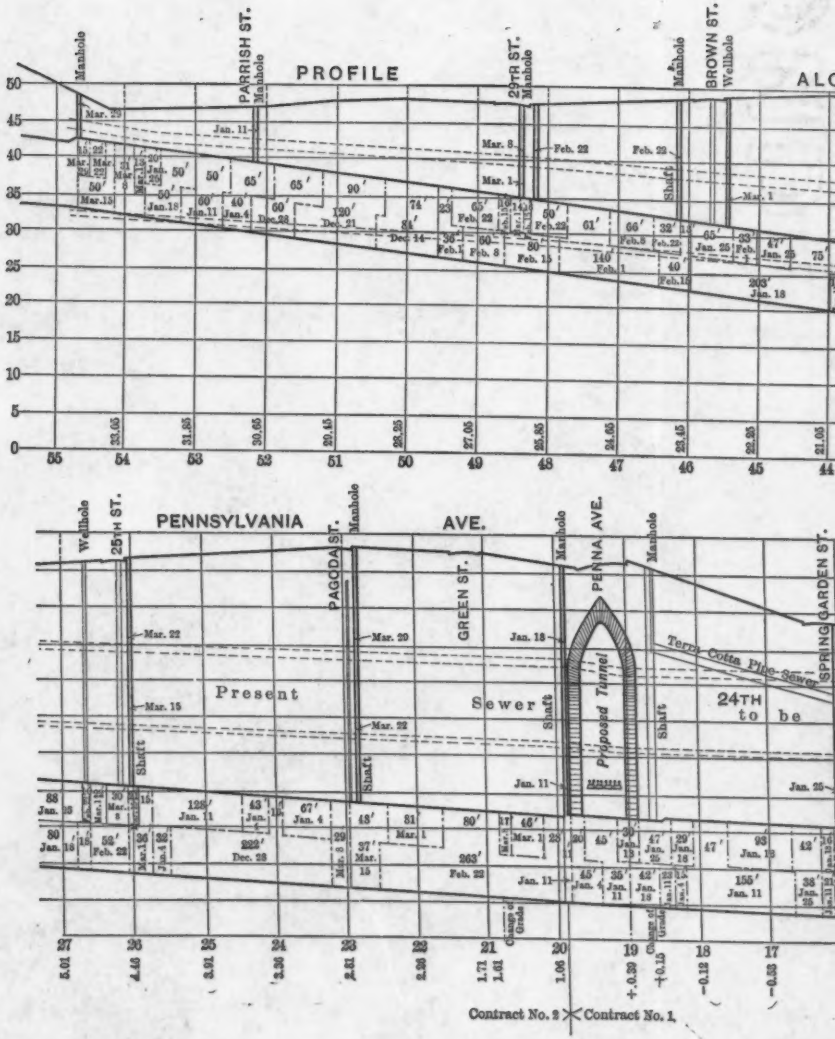
TABLE No. 8.—SUMMARY OF SEWER WORK.

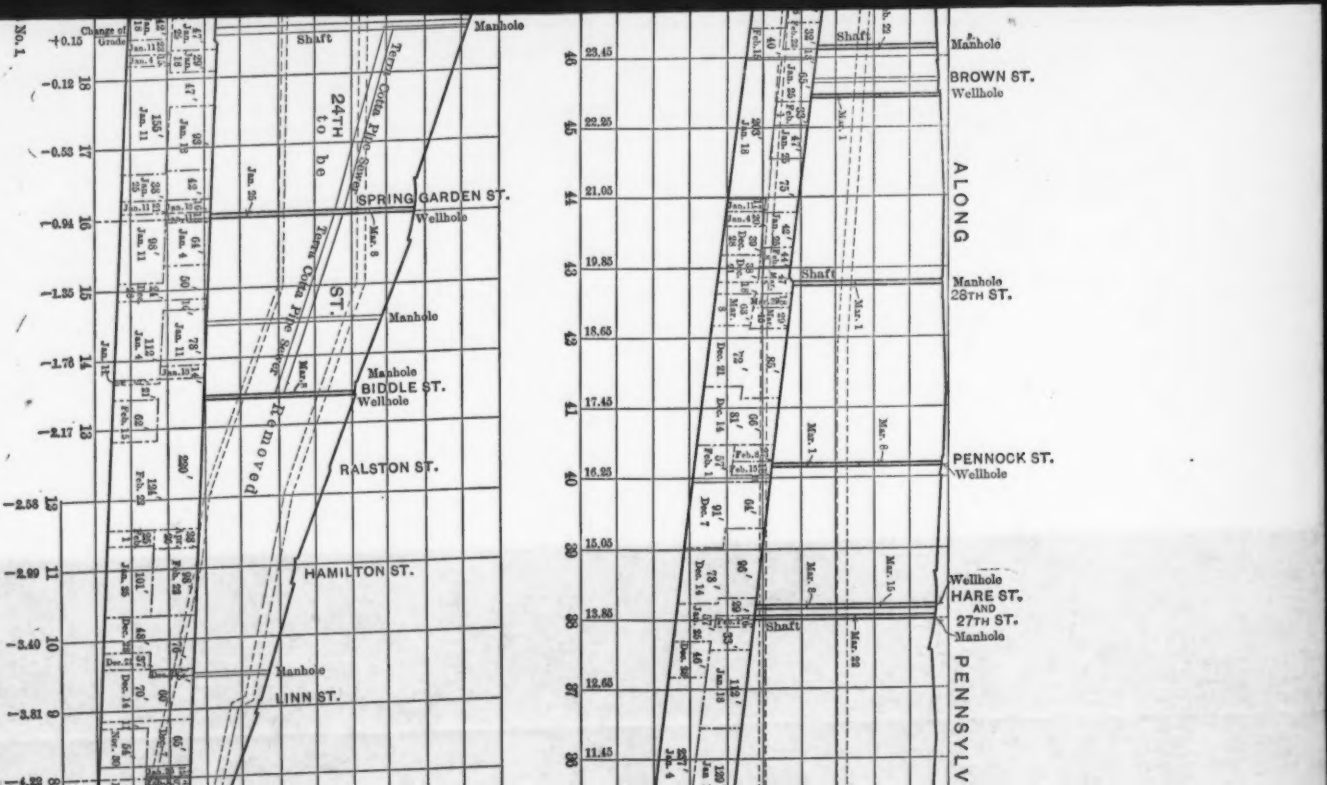
System.	Contract.	Shafts.	Total length in feet.	Length in tunnel, in feet.	Total cost.
Twenty-fourth St. and Pennsylvania Ave.	No. 1	9	1 988.03	1 001.03	$92 586.42
Twenty-fourth St. and Pennsylvania Ave.	No. 2	16	3 470.66	2 878.02	126 496.15
Callowhill Street	No. 1	8	3 094.61	1 751.87	80 342.75
Callowhill Street	No. 2	12	2 953.20	2 953.20	69 662.71
Callowhill Street	No. 3	9	2 467.97	2 060.97	35 976.81
Twelfth Street	.....	....	1 398.00	.....	22 823.49
		54	15 372.47	10 645.09	$427 888.33

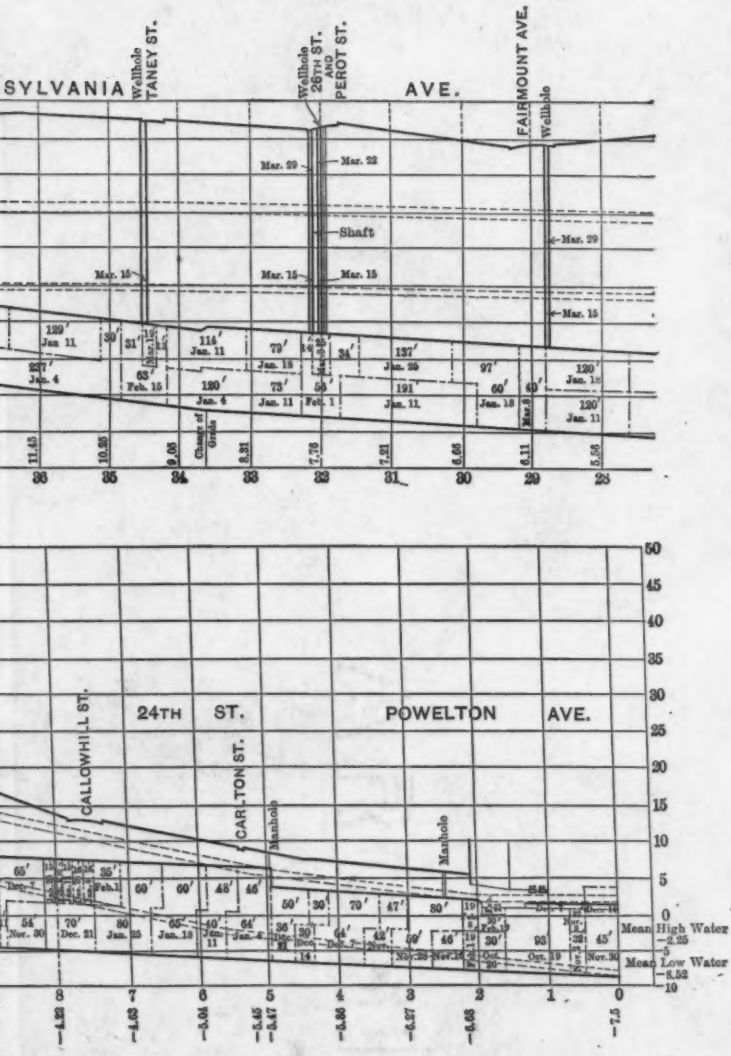
GENERAL SEWER NOTES.

Except on Twelfth St., Buttonwood St. and Callowhill St., west of Twenty-second St., no provision was made in the sewers for house connections, on account of the depth of the main sewer beneath the street. Where it was necessary to provide for such connections, auxiliary pipe sewers were constructed at a higher elevation, and these emptied into the deep sewers through wellholes at suitable intervals.

In many cases, where high-level sewers existed already, it was possible to maintain them with their house connections intact by building


PROFILE
PARRISH ST.
29TH ST.
BROWN ST.
Manhole
Wellhole
Shaft
Present Sewer
Proposed Tunnel
Terra Cotta Pipe Sewer
PENNSYLVANIA AVE.
PAGODA ST.
GREEN ST.
PENNA. AVE.
SPRING GARDEN ST.
25TH ST.
24TH to be
Change of Grade
Contract No. 2
Contract No. 1


No. 1.
Change of Grade
+0.15
+0.12
+0.53
+0.94
+1.35
+1.76
+2.17
+2.58
+2.99
+3.40
+3.81
+4.22
18
17
16
15
14
13
12
11
10
9
8
Shaft
Manhole
Terra Cotta Pipe Sewer
24TH to be
SPRING GARDEN ST.
Wellhole
Mar. 8
Terra Cotta Pipe Sewer
ST.
Manhole
Manhole
BIDDLE ST.
Wellhole
Removed
RALSTON ST.
HAMILTON ST.
Manhole
LINN ST.
23.45
22.95
21.05
19.85
18.65
17.45
16.25
15.05
13.85
12.65
11.45
46
45
44
43
42
41
40
39
38
37
36
Shaft
Manhole
BROWN ST.
Wellhole
ALONG
Shaft
Manhole
28TH ST.
PENNOCK ST.
Wellhole
Wellhole
HARE ST.
AND
27TH ST.
Manhole
Shaft
PENNSYLV


SYLVANIA AVE.
Wellhole TANEY ST.
Wellhole 26TH ST. AND PEROT ST.
FAIRMOUNT AVE.
Wellhole
Mar. 29
Mar. 22
Shaft
Mar. 29
Mar. 15
Mar. 15
Mar. 15
Mar. 15
129' Jan. 11
93' Jan. 4
65' Feb. 15
114' Jan. 11
120' Jan. 6
79' Jan. 18
73' Jan. 11
50' Feb. 1
34'
137' Jan. 26
191' Jan. 12
97'
60' Jan. 18
49' Mar. 3
120' Jan. 18
120' Jan. 11
Change of Grade
11.45
10.85
9.66
8.81
7.79
7.21
6.66
6.11
5.56
36
35
34
33
32
31
30
29
28
24TH ST.
POWELTON AVE.
CALLOWHILL ST.
CARLTON ST.
Manhole
Manhole
65' Dec. 7
54' Nov. 30
70' Dec. 21
80' Jan. 25
65' Jan. 18
40' Jan. 11
64' Jan. 4
36' Dec. 14
30' Dec. 7
44' Dec. 7
60' Feb. 1
60'
48'
46'
50' Nov. 28
30'
70'
47'
80'
19' Feb. 19
30' Feb. 19
46' Nov. 26
30' Oct. 20
93' Oct. 19
32' Nov. 30
45'
50
45
40
35
30
25
20
15
10
5
0
Mean High Water
—2.25
Mean Low Water
—8.52
8
7
6
5
4
3
2
1
0
—4.23
—4.63
—5.04
—5.45
—5.47
—5.86
—6.27
—6.63
—7.5

the new sewer in tunnel and not disturbing the surface of the street. Where it was necessary to give both old and new sewers the same alignment, side shafts were sunk, or the old sewer was carried across the shaft in a flume during construction. Wherever practicable, the shafts were sunk where manholes were required, thus accomplishing a double purpose.

The details of manholes, wellholes, etc., are shown in Figs. 8 to 11, which explain themselves sufficiently.

Plate III shows the weekly progress made in excavation in tunnel and open cut on the Twenty-fourth St. and Pennsylvania Ave. System, and Plate IV shows the weekly progress made in laying the brickwork on the same system. As this work was pushed rapidly, the data may prove of interest. Work was always carried on in the tunnel excavation practically at night. Brickwork was only laid by day.

Engineering.

Under the ordinance authorizing this work, the Director of the Department of Public Works, who has supervision of the Engineering Bureaus of the City, was authorized and directed to appoint such assistant engineers, draughtsmen and inspectors as might be necessary for the efficient execution of the works.

The work was placed in charge of George S. Webster, M. Am. Soc. C. E., Chief Engineer, Bureau of Surveys, which Bureau has jurisdiction over such work, under the Department of Public Works. Mr. George E. Datesman is the Principal Assistant Engineer of this Bureau.

In June, 1894, Samuel Tobias Wagner, M. Am. Soc. C. E., was appointed First Assistant Engineer in charge of the work, and Mr. Charles H. Swan, Chief Draughtsman. Mr. Swan had for some time previously been engaged upon the preparation of the plans. In August, 1894. Mr. Richard I. D. Ashbridge was appointed Second Assistant Engineer in charge of the work of construction of the sewers. Mr. Charles H. Ott, with a corps of assistants, was delegated to assist in giving lines and grades.

Owing to the difficulties of giving the lines and grades on this work, and the rapidity with which it was carried on at a large number of points at the same time, and on account of the uniformly good

results obtained, the greatest credit is due to the engineers in the field.

Under the ordinance, the Director of the Department of Public Works was directed to confer during the progress of the work with an engineer to be appointed by the Philadelphia and Reading Railroad Company, in regard to carrying out the specifications and securing the proper performance of the contracts. On March 30th, 1894, the late John A. Wilson, M. Am. Soc. C. E., was appointed Consulting Engineer to represent the Railroad Company. After Mr. Wilson's death, which occurred on January 19th, 1896, Joseph M. Wilson, M. Am. Soc. C. E., was appointed Consulting Engineer. Mr. John A. Wilson was closely identified with the preparation of the studies and the details of the work, with special reference to the railroad interests.

DISCUSSION.

Messrs. Webster and Wagner.

GEORGE S. WEBSTER and SAMUEL TOBIAS WAGNER, Members, Am. Soc. C. E. (by letter).—It will be noticed by an examination of Fig. 4, which is the main drainage plan of the sewers, that the grades on the main lines are very light for the conditions which had to be met. In place of compensating for the velocity on the curves by increasing the grades, it was deemed expedient to keep the same rate of grade throughout and add to the velocity by reducing the friction. This was done by plastering the inverts on curves with Portland cement mortar ½ in. thick. This plastering was usually done after the invert was laid and before the centers for the arch were placed. In the case of Contract No. 1 of the Callowhill Street System the work of plastering was delayed until the sewage was passing through the system, with the result already referred to in the paper.

All the brickwork of the sewers, except that in the wellholes, was laid in natural cement mortar. In the wellholes, Portland cement was specified. In all cases the mortar was mixed in the proportion of 1 part of cement to 2 parts of sand. Briquettes, 1 sq. in. in cross-section, when made from natural cement mortar from the mixing box, were required to develop an ultimate tensile strength of 40 lbs., after having been 1 day in the air and 6 days in water. In the case of Portland cement, under the same conditions, a strength of 150 lbs. was required.

The other requirements of the natural cement, which, of course, represented the greater part of the work, were as follows: It shall weigh not less than 112 lbs. per imperial bushel. The residue upon a No. 50 sieve shall not exceed 4% by weight, upon a No. 100 sieve 25%, and upon a No. 200 sieve 50 per cent. Pats of cement ½ in. thick, temperature between 60 and 70° Fahr., shall develop initial set in not less than 10 minutes and hard set in not less than 30 minutes, the amount of water used being just sufficient to form a stiff plastic paste.

The following tensile strengths were required:

24 hours (in water after hard set)	75 lbs.
7 days (1 day in air, 6 days in water)	150 "
28 days (1 day in air, 27 days in water)	250 "

Mortar composed of 1 part of cement and 1 part of standard quartz sand was required to develop an ultimate tensile strength of 75 lbs. after 7 days.

All concrete used was composed of 1 part of natural cement, 2 parts of sand, and 4 parts of stone or furnace slag.

The results of all soundings made adjacent to the line of the sewer were platted on the working drawings of the sewers, for the benefit of the contractors in making their estimates. The following note was placed upon all such plans: "Soundings shown are not guaranteed or

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binding upon the City of Philadelphia." As a result of this note no claims were made where any differences between the soundings and the workings were found to exist.

A summary of the character of the material encountered is approximately as follows: Beginning at Thirteenth St., where the depths of the sewers were smallest, the excavation was through clay and gravel. The invert of the sewer, however, usually rested upon rotten rock of a micaceous nature. The cross sewer on Fifteenth St. was mostly in gravel, and the workings naturally contained a considerable amount of ground-water. On Sixteenth St. a considerable amount of rather hard micaceous rock was met, the invert being entirely in this material. From this point to between Nineteenth and Twentieth Sts. clay, gravel and rock of varying degrees of hardness, irregularly located, was encountered. On Seventeenth and Eighteenth Sts. very rotten micaceous rock, acting like quicksand, was discovered, requiring great care in the workings. Between Nineteenth and Twenty-second Sts., and on the Twentieth St. sewer, hard gneiss was found. As the work approached the river the rock gradually ran out, until, between Twenty-third and Twenty-fourth Sts., it had entirely disappeared.

On Twenty-fourth St. from Callowhill St. to Pennsylvania Ave. reasonably hard, and in some cases very hard, gneiss was met. Beneath Pennsylvania Ave. was a bed of gravel, afterward discovered to be of considerable extent; the sewer invert, however, was on rock. From this point to Twenty-ninth St. the excavation was through soft micaceous rock which blew to pieces and came out of the shafts to all purposes in the form of sand. From Twenty-ninth to Thirtieth St. the excavation was through clay and gravel, as the sewer was not deep.

The character of the rock east of Twenty-ninth St. was the same 40 ft. below the surface as immediately under the top soil.

The difficulty of making deep open-cut excavations adjacent to buildings, without causing settlement, is well known. This is especially true if the foundations of the buildings be inadequate, or be upon a formation which is readily affected by the action of the elements upon exposure, or if the buildings be old and poorly constructed. In many cases the trouble is aggravated if it is necessary to use an explosive to assist in the removal of the excavated material.

If, on the other hand, the excavation is made in tunnel, with careful timbering in soft material, or with properly regulated charges when blasting through rock, the danger is materially lessened, especially if all open spaces between the structure which is to be built and the surrounding material are compactly filled with masonry, carefully laid.

The construction of these sewers has been an excellent proof of the truth of this statement. Probably seven-eighths of the entire line was through streets lined on either side with buildings of all kinds, dwellings, store-houses and manufactories. In no case, where the sewers

were constructed in tunnel, was any damage done to property, with the exception of the cases referred to in the paper. All such damage was caused by blasting, and, without doubt, was brought about by the use of unduly large charges. In the case mentioned in Contract No. 2, Pennsylvania Avenue System, a 48-in. water main, immediately over the tunnel, was broken by blasting, and an ice manufacturing plant, similarly situated, was compelled to stop work on account of the leakage of the joints in the ammonia pipes, which, it was claimed, was caused by the blasting. In this latter case it was the intention to remove the plant by widening the street, so that the damage was not unexpected. On Contract No. 2, Callowhill Street System, the only damage was caused by the interference with the adjustments of very sensitive machine tools in an adjoining plant. In this case, further damage was prevented by the Chief Engineer, who gave instructions regulating the size of the blasts. The damage in this case, recovered in court from the contractor, amounted to $300, which was the full amount claimed by the plaintiff. In no case, where the sewers were in tunnel, was there any damage whatever caused by settlement, nor were any settlements in the street paving afterward discovered, except in a few cases over the points where shafts had been sunk in order to reach the tunnel. Messrs. Webster and Wagner.

The only open-cut work was in comparatively shallow depths. On Callowhill St., between Twenty-second and Twenty-third Sts., there was a slight settlement of the curb and part of the sidewalk pavement nearest to the trench. This was rectified by the contractor at a slight expense.

On Twenty-fourth St. considerable damage to adjoining buildings was caused by the construction of the temporary flume, because it was excavated through rock, and, also, because of the very old and dilapidated character of the buildings. The expense of repairing these buildings was borne by the contractor, as already stated. The location of the flume on the sidewalk was determined by the contractors as an incidental to the work.

The effect of the sub-soil drainage upon the surrounding neighborhood, caused by the construction of the sewers, has been marked. A very considerable amount of this water was encountered on the cross streets from Fifteenth to Eighteenth Sts., and was tapped into the sewers. When the excavation for the retaining walls was made, afterward, no trouble whatever was caused by water, in many cases the soil being perfectly dry where formerly running sand was encountered.

It is the purpose of the writers to present in a future paper a description of the construction of the Subway and Tunnel proper, in which the work of underpinning, the construction of the retaining walls and the bridges, as well as the special railroad and municipal features of the operation, will be elaborated.